Beyond Transport Time: modeling time use, understanding time values.

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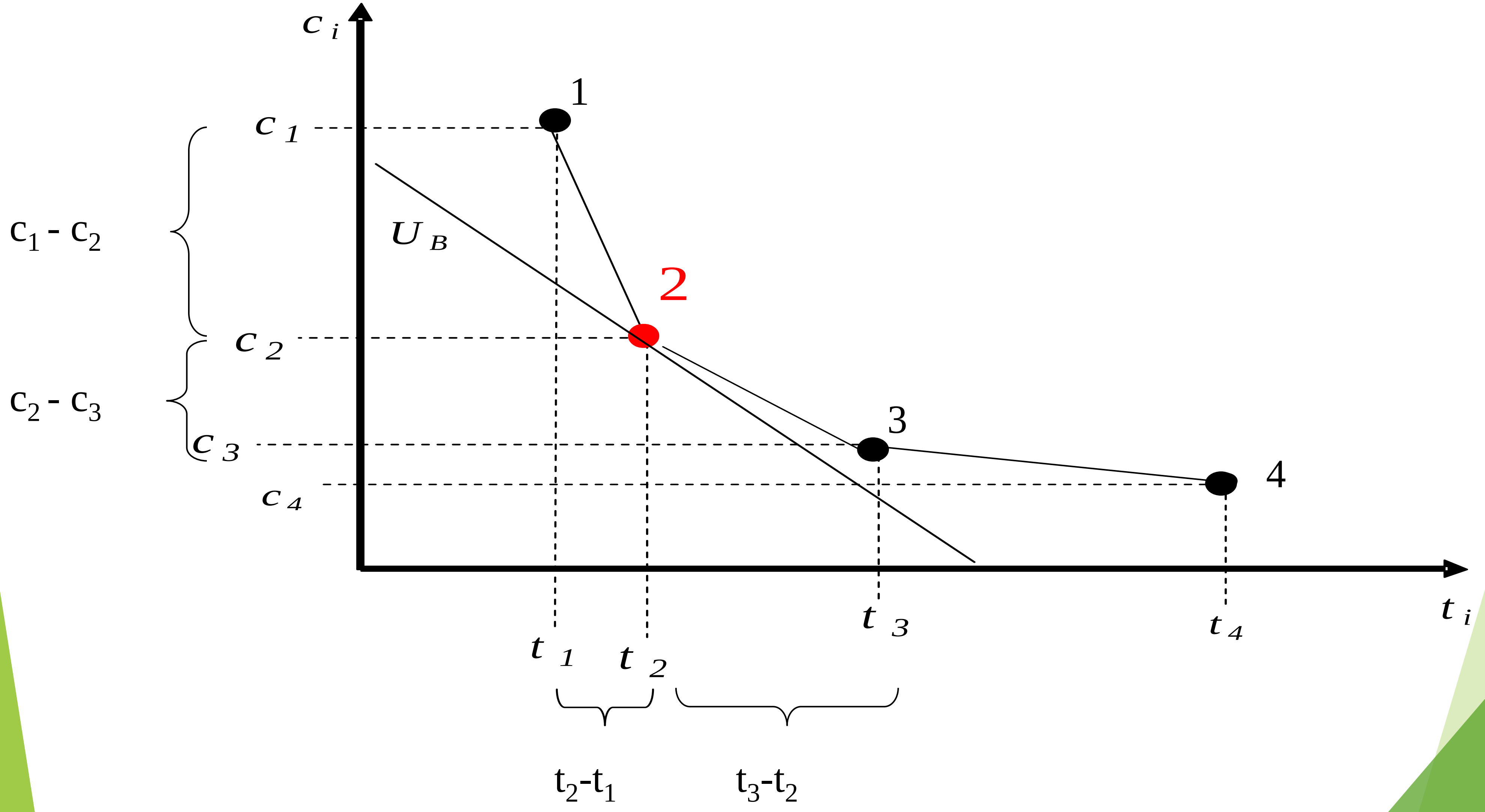
Valuing Time?

Time constraint → Time needs → Time valuation

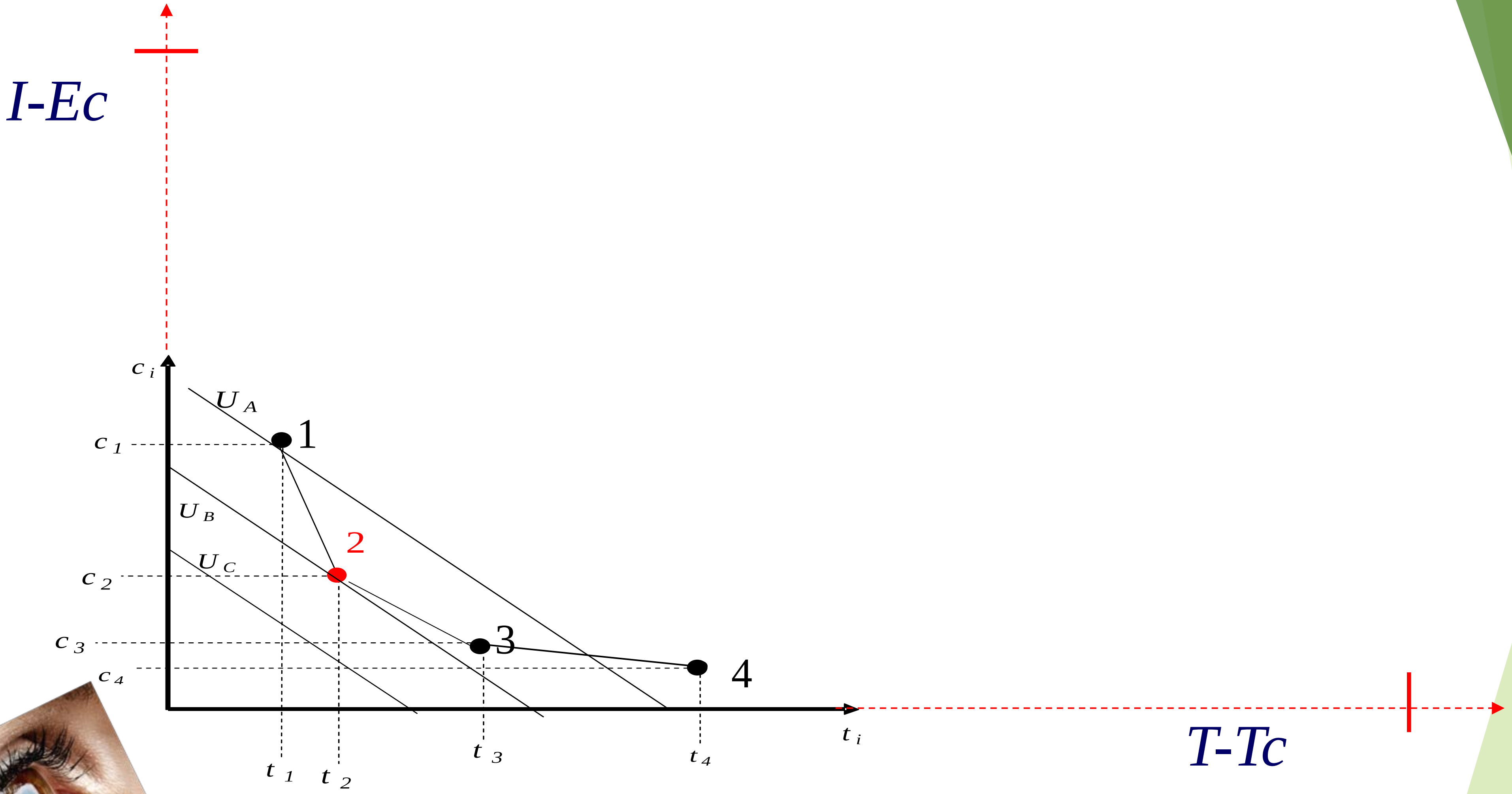
- What is the Value of Time?
  - The value of assigning it to a satisfying activity?
  - The value of diminishing it in an unpleasant activity?
  - The wage rate?

The time you enjoy wasting is not wasted time.
--Bertrand Russell

Travel and activities: two perspectives on VoTT.

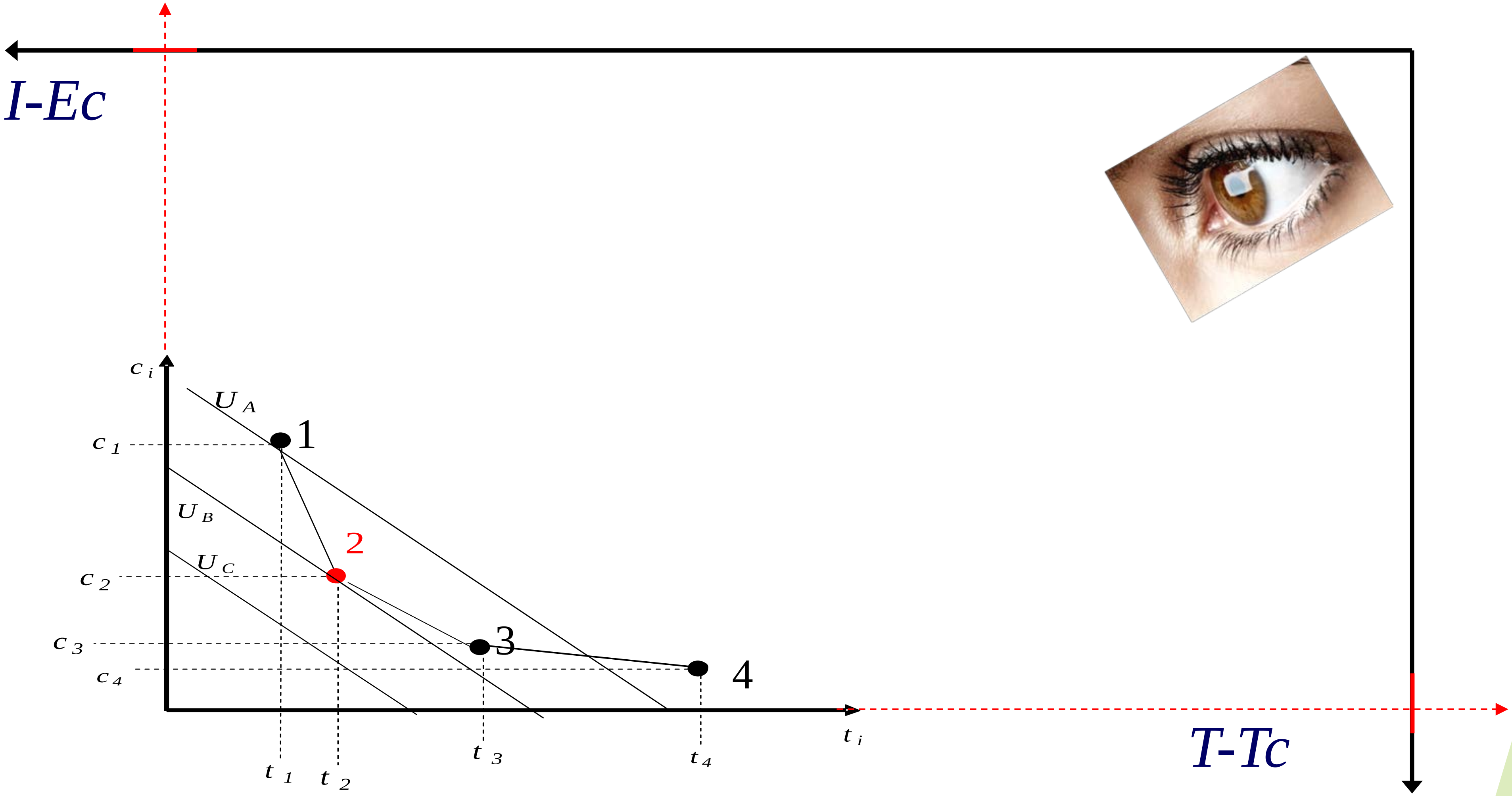


Perspective 1

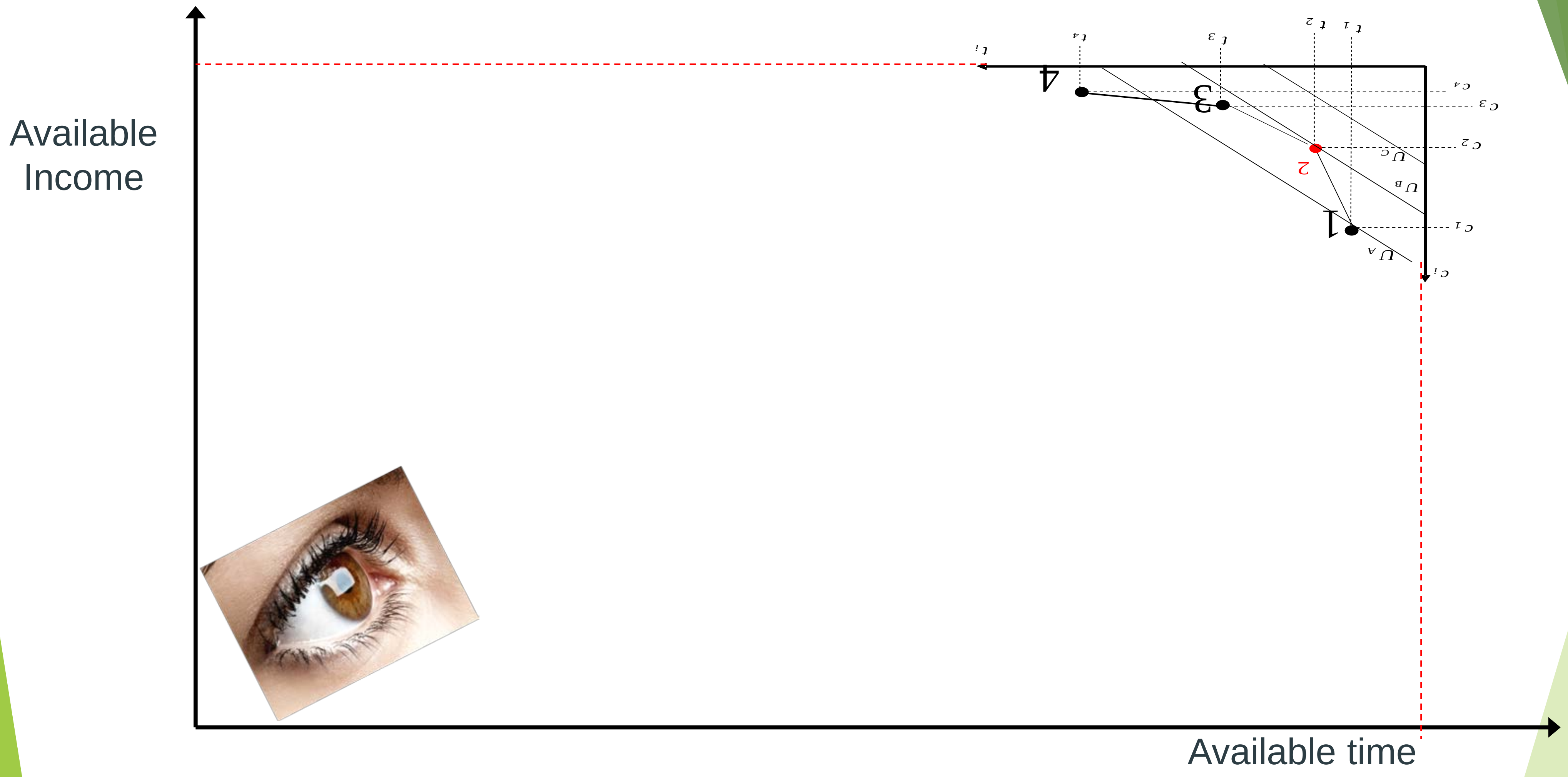


Diminish travel time by paying more…

or



Perspective 2



... increase discretionary free time by diminishing available income

The value of travel time savings

$$V_i = \alpha_i + \beta c_i + \gamma t_i + \ldots$$

$$VTTS = \frac{\partial V_i / \partial t_i}{\partial V_i / \partial c_i} = \frac{\gamma}{\beta}.$$

What lies behind the *VTTS*?

Examine the underlying microeconomic theory

Towards travel time value: the discrete choices paradigm

$$\underset{X,j}{Max}\, U\left(X, Q_j\right)$$
$$\sum P_i X_i + c_j \leq I$$
$$J \in M$$

$$\rightarrow \quad \underset{X}{Max}\, U\left(X, Q_j\right) \qquad \sum P_i X_i \leq I - c_j \quad \rightarrow \quad X^*\left(P, Q_j, I - c_j\right)$$

conditional demands

$$U\left[X^*\left(P, Q_j, I - c_j\right), Q_j\right] = V\left(P, Q_j, I - c_j\right) \equiv V_j$$

Conditional Indirect Utility Function (truncated)

$$\underset{j \in M}{Max}\, V\left(P, Q_j, I - c_j\right) \rightarrow \quad V_k \,?\, V_L \quad \forall_{k,L \in M}$$

$$MUI = \lambda = \frac{\partial V}{\partial I} = -\frac{\partial V_j}{\partial c_j}$$

Marginal Utility of Income

$$SVq_{ji} = \frac{\partial V_j / \partial q_{ji}}{\partial V_j / \partial I}$$

Subjective Values

Towards travel time value: Becker's model (1965)

- Max $U(Z)$ $\quad Z(X, T)$

  (1) $\Sigma P_i X_i = wW$

  (2) $\Sigma T_j + W = \tau$

- Replacing (2) in (1)

  $\Sigma P_i X_i + w \Sigma T_j = \tau w$

Value of Time = w

- "Time can be converted into money…"
- All activities "value" w

→ **Discrete mode choice** (Train and McFadden, 1978)

$$\left.\begin{array}{r} Max \quad U(G,L) \\ G + c_i = wW + E \\ W + L + t_i = T \end{array}\right\} \begin{array}{c} \underset{i\in M}{Max}\left\{\underset{W}{Max}\, U\left[G(W,C_i), L(W,t_i)\right]\right\} \\ W^*(C_i,t_i) \\ U_i \equiv U\left[G(W^*,C_i), L(W^*,t_i)\right] \end{array}$$

if $U(G,L) = K\, G^{1-\beta} L^{\beta}$

$$U_i = K(1-\beta)^{1-\beta}\beta^{\beta}\left[w^{-\beta}(E - c_i) + w^{1-\beta}(T - t_i)\right]$$

$$V_i = -w^{-\beta}C_i - w^{1-\beta}t_i \qquad \text{TCIUF}$$

$$WPSTT = \frac{\partial V_i / \partial t_i}{\partial V_i / \partial c_i} = w$$

Value of Time = w

$$V = U + \varepsilon$$

Why diminish Travel Time?

Value of diminishing Travel Time = Value of performing another activity + Perception of travel itself

De Serpa's Model (1971)

$$Max \quad U = \left(X_1,\ldots,X_n,T_1,\ldots,T_n\right)$$

$$\sum_{i=1}^{n} P_i X_i = wT_w + I_f \rightarrow \lambda$$

$$\sum_{i=1}^{n} T_i = \tau$$

$$T_i \geq a_i X_i \quad i = 1,\ldots,n$$

Value of time as a resource:	$\frac{\mu}{\lambda}$
Value of time as a commodity:	$\frac{\partial U / \partial T_i}{\lambda}$
Value of saving time in activity i:	$\frac{\kappa_i}{\lambda}$

$$\frac{\kappa_i}{\lambda} = \frac{\mu}{\lambda} - \frac{\partial U / \partial T_i}{\lambda}$$

$$\frac{\mu}{\lambda} = w + \frac{\partial U / \partial T_w}{\lambda}$$

What is behind the willingness to pay to save travel time (WPSTT)?

$$\frac{\kappa_i}{\lambda} = \frac{\mu}{\lambda} - \frac{\partial U/\partial T_i}{\lambda}$$

$$\frac{\mu}{\lambda} = w + \frac{\partial U/\partial T_w}{\lambda}$$

WPSTT = Value of performing another activity − Value of time assigned to travel

- *Leisure*
- *Work*

Value of Leisure = Wage rate + Value of Work

A MODEL FOR ACTIVITY TIME ASSIGNMENT AND TRAVEL

(Jara-Díaz and Guevara, 2003)

$$Max \quad U = \Omega T_w^{\theta_w} T_t^{\theta_t} \prod_{i \in I} T_i^{\theta_i} \prod_{k \in K} X_k^{\eta_k}$$

$$wT_w - \sum_{k \in K} P_k X_k - c_t \geq 0 \rightarrow \lambda$$

$$\tau - T_w - T_t - \sum_{i \in I} T_i = 0 \rightarrow \mu$$

$$T_t - T_t^{MIN} \geq 0 \rightarrow \kappa$$

$$\frac{\mu}{\lambda} = \frac{1-2\beta}{1-2\alpha} \frac{(wT_w - c_t)}{(\tau - T_w - T_t^{MIN})}$$

Transport time analysis being expanded towards all activities...

Corollaries

- Pleasant travel **not enough** for *SVTTS* to be negative
- $$$ → faster or more comfortable?
- Implicit solution for T_w
- Implicit equations for leisure activities?

A MODEL SYSTEM FOR ACTIVITY TIMES AND GOODS CONSUMPTION

(Jara-Díaz and Guerra, 2003)

$$\underset{s.a.}{Max}\, U = \Omega T_w^{\theta_w} \prod_i T_i^{\theta_i} \prod_k X_k^{\eta_k}$$

$$I_f + wT_w - \sum_k P_k X_k \geq 0 \rightarrow \lambda$$

$$\tau - T_w - \sum_i T_i = 0 \rightarrow \mu$$

$$T_i - T_i^{Min} \geq 0 \quad \forall i \rightarrow \kappa_i$$

$$X_k - X_k^{Min} \geq 0 \quad \forall k \rightarrow \varphi_k$$

$$Value\ of\ leisure = \frac{\mu}{\lambda} = \frac{(1-2\beta)(wT_w^* - E_c)}{(1-2\alpha)(\tau - T_w^* - T_c)}$$

$$Value\ of\ work = \frac{\partial U / \partial T_w}{\lambda} = \frac{(2\alpha + 2\beta - 1)(wT_w^* - E_c)}{(1-2\alpha)T_w^*}$$

$$\frac{\mu}{\lambda} = w + \frac{\partial U / \partial T_w}{\lambda}$$

$$T_w^* = \left[(\tau - T_c)\beta + \frac{E_c}{w}\alpha\right] + \sqrt{\left[(\tau - T_c)\beta + \frac{E_c}{w}\alpha\right]^2 - \frac{E_c}{w}(2\alpha + 2\beta - 1)(\tau - T_c)}$$

$$T_i^* = \frac{\tilde{\theta}_i}{(1-2\beta)}(\tau - T_w^* - T_c) \quad \forall i \in I$$

$$X_k^* = \frac{\tilde{\eta}_k (wT_w^* - E_c)}{P_k (1-2\alpha)} \quad \forall k \in K$$

$\alpha, \beta, \theta_i, \eta_k$

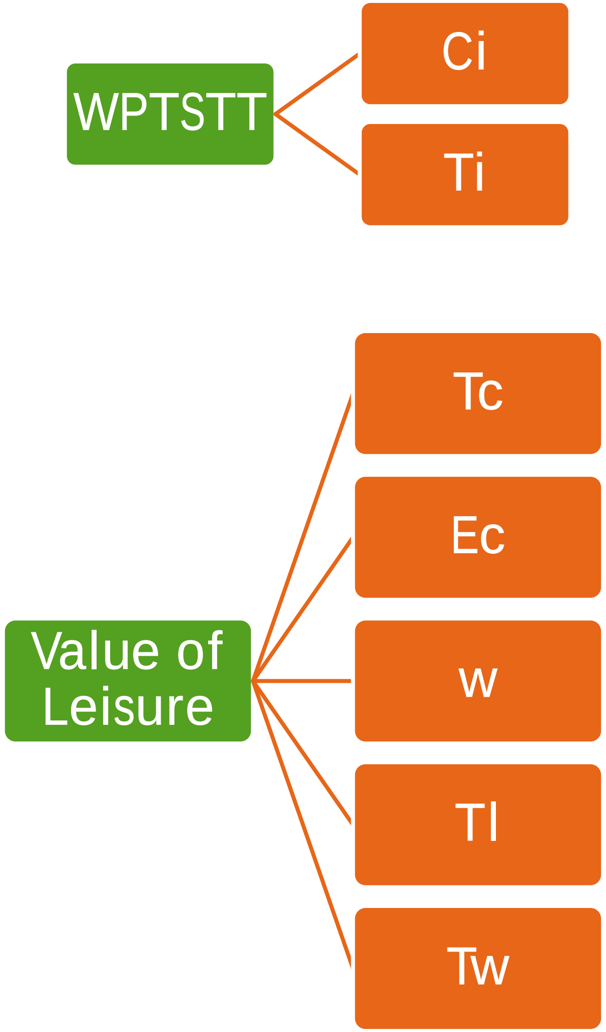
...towards a general time use model

Corollaries

- E_c and T_c play key role.
- Model requires observations involving complete work-leisure cycles.
- $T_i\,(E_c,\ T_c,\ w)$ system looks like a reduced form of a "structural equations" model.
- Values of work, leisure, travel and *SVTTS* can be calculated
- $T_w\,(E_c,\ T_c,\ w)$ equation is a more complete labor supply equation (goods-leisure particular case)
- Change in time assignment (labor and leisure activities) can be predicted after changes in E_c and/or T_c
- One can estimate the labor supply equation only (to get α and β) or a system of equations including up to N-1 unconstrained activities and up to M-1 unconstrained goods.

$$\frac{\mu}{\lambda} = w + \frac{\partial U/\partial T_w}{\lambda} \quad \therefore \quad \frac{\mu/\lambda}{w} + \frac{-(\partial U/\partial T_w)/\lambda}{w} = 1$$

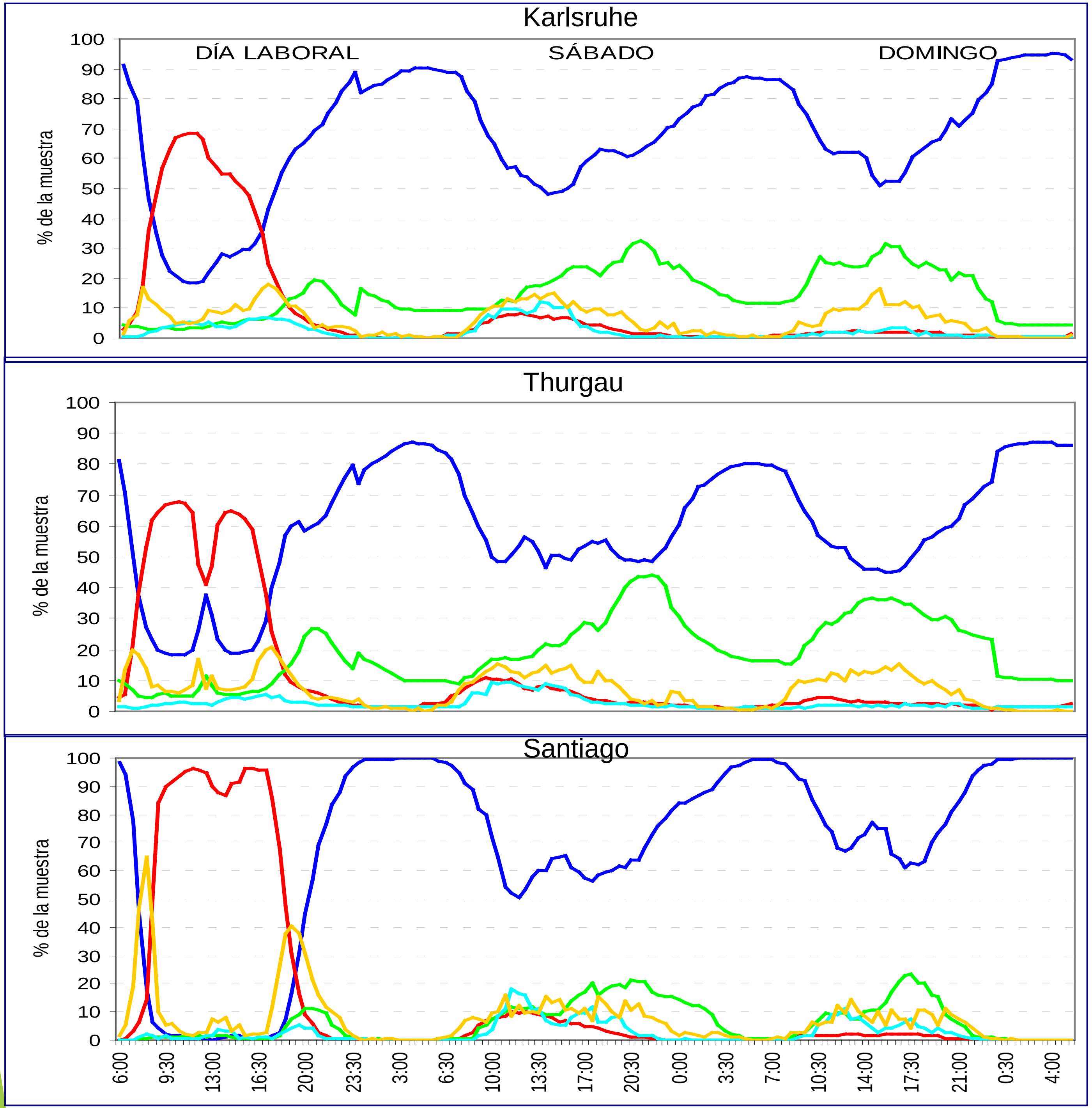
Behind and beyond the willingness to pay to save travel time



$$\frac{\kappa_i}{\lambda} = \frac{\mu}{\lambda} - \frac{\partial U/\partial T_i}{\lambda}$$

$$\frac{\mu}{\lambda} = w + \frac{\partial U/\partial T_w}{\lambda}$$

Activity Patterns

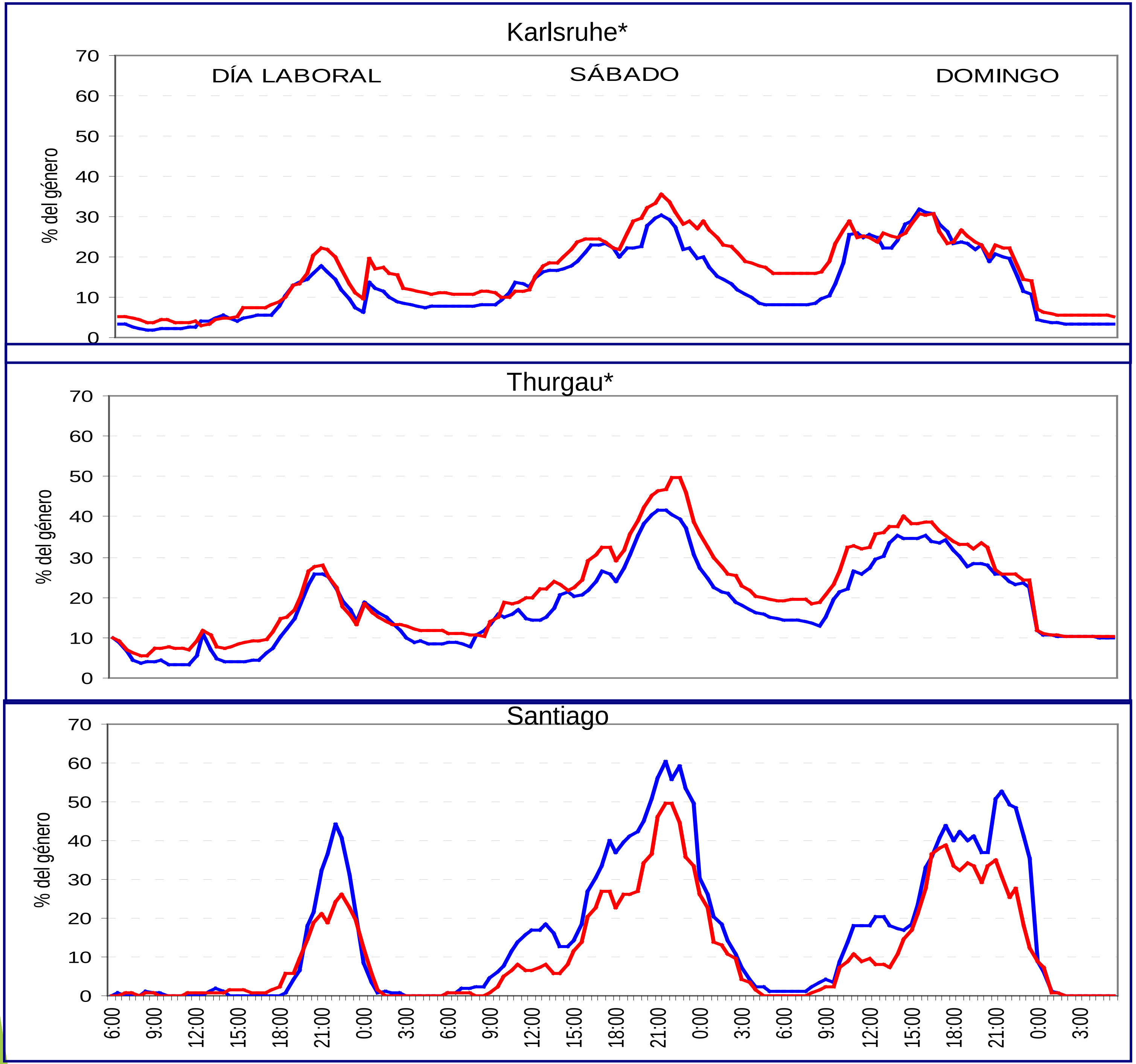


- Home
- Work
- Out of home entertainment
- Shopping and errands
- Trips

Values of time [US$/hour] (Jara-Diaz et al, 2008)

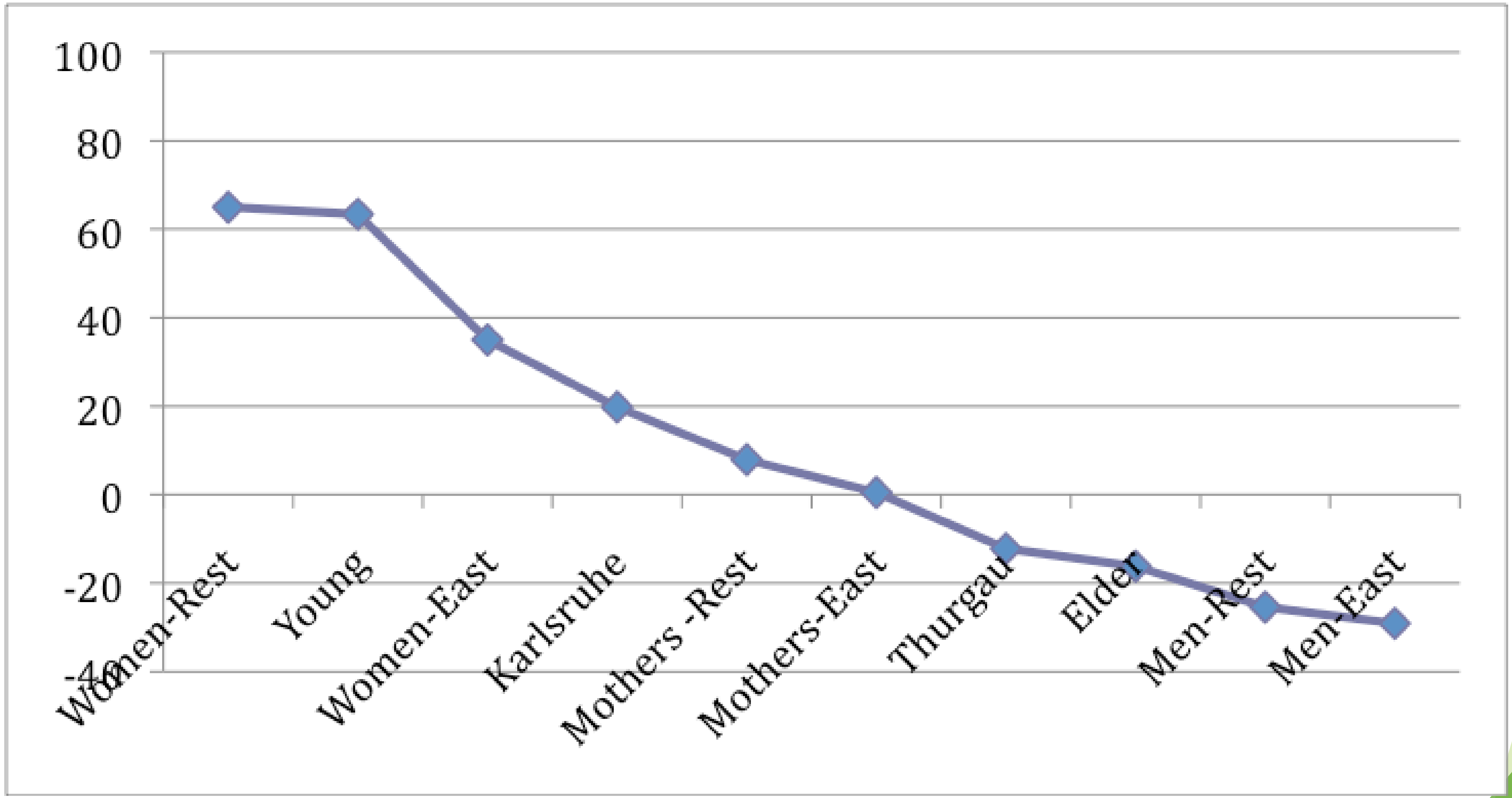
	Santiago		Karlsruhe		Thurgau	
Value of	Value	% wage	Value	% wage	Value	% wage
Leisure	2.75	61.8	11.0	103.7	26.7	87.8
Work	-1.70	38.2	0.4	-3.7	-3.7	12.2
Wage rate	4.45	100.0	10.6	100.0	30.4	100.0
WPSATT	3.49		38.5			
VTT	-0.74	21.2	-27.5	71.4		

Entertainment Pattern by gender



Men
Women

Value of work as a percentage of the wage rate in Santiago (Jara-Diaz, Munizaga and Olguín, 2013)



So far

- Understanding utility as a **TCIUF** facilitates specification and interpretation (and avoids misinterpretations)

- Behind the **TCIUF** always is a system of activities and goods consumption equations

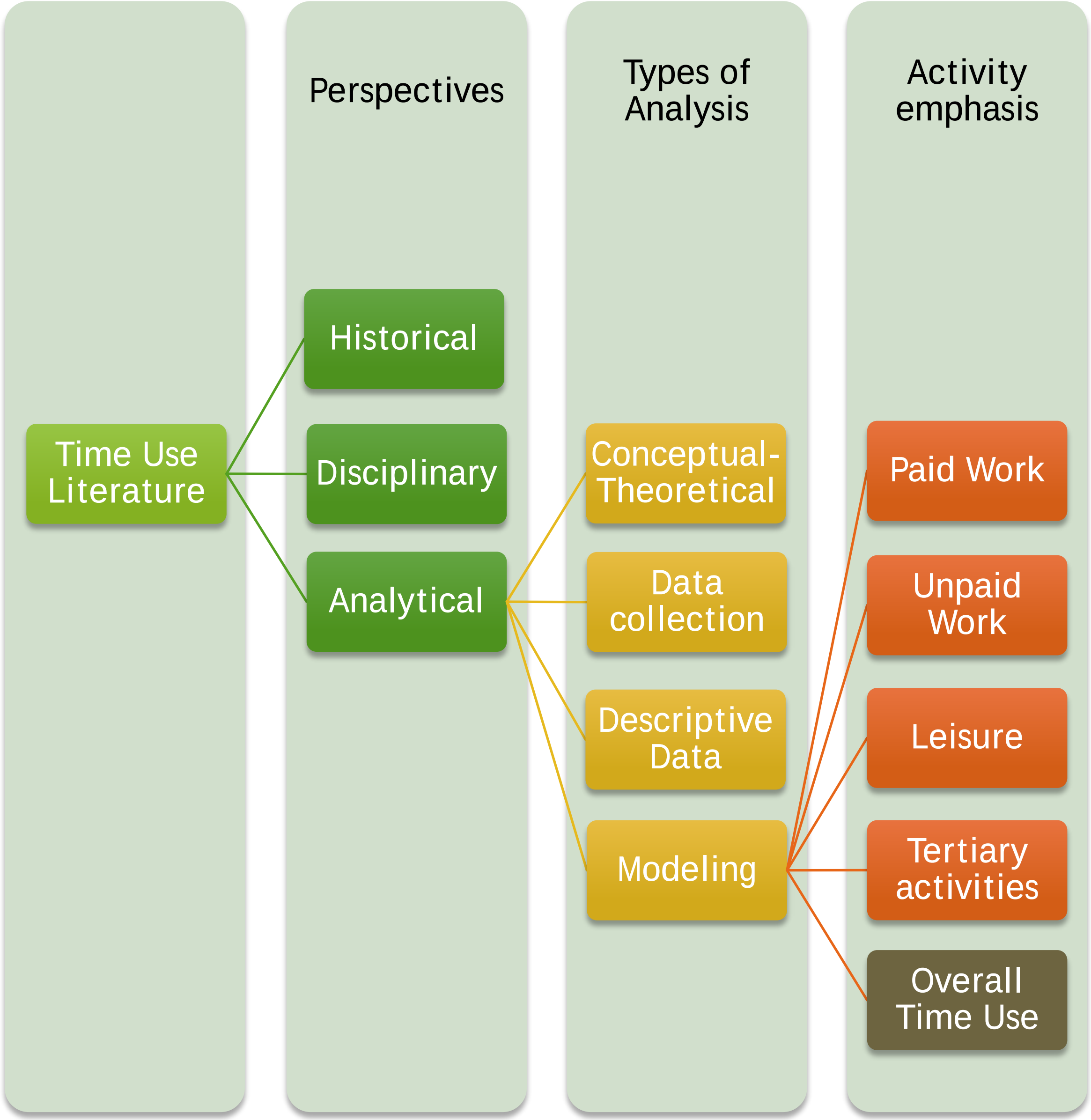
- Gross classification of activities:
  a. Those one would like to increase but can not because of time budget (leisure);
  b. Those one would like to decrease but can not because of technical constraints ;
  c. Work and others.

- For b-type activities, Value of reduction = value of doing something else + value of diminishing mandatory time assigned.

- Observed Time Use in work-leisure cycles permits empirical estimations of these values of time using econometric models: transport (four decades), activities.

- Applications so far (Santiago, Karlsruhe, Thurgau, U.S.A.) show that:
  - Value of work time can be positive or negative.
  - Value of leisure can be different from the wage rate.
  - Increasing available time can be more important than travel displeasure.
  - Better to use segments than include socio-demographic variables in *U*.

Time Use Literature



REVEALED WILLINGNESS TO PAY FOR LEISURE (Jara-Díaz and Astroza, 2013)

$$\frac{\dfrac{\partial U}{\partial T_R}}{\lambda} + \frac{\dfrac{\partial U}{\partial X_R}}{\lambda}\frac{\partial g_R}{\partial T_R} = \frac{\mu}{\lambda} + RWPL$$

Link Between Structural and Microeconomic Models of Time Use

Introducing relations between activities and goods consumption in microeconomic time use models (Jara-Díaz et al., 2015)

$$Max\ U(\boldsymbol{T},\boldsymbol{X}) = \Omega T_w^{\theta_w} \prod_i T_i^{\theta_i} \prod_j X_j^{\varphi_j}$$

$$s.t. \quad wT_w + I - \sum_j P_j X_j - c_f \geq 0 \qquad (\lambda)$$

$$\tau - T_w - \sum_i T_i = 0 \qquad (\mu)$$

$$T_i - T_i^{\min} \geq 0 \quad \forall i \qquad (\kappa_i)$$

$$X_j - \alpha_j T_j \geq 0 \quad \forall j \qquad (\psi_j)$$

$$\frac{\mu}{\lambda} = \frac{\theta}{\phi} \frac{\left(wT_w - E_c' - \sum_{j \in A^F \cap G^R} P_j \alpha_j T_j \right)}{\left(\tau - T_w - T_c - \sum_{k \in A^F \cap G^R} T_k \right)}$$

For max LL estimation, consider stochastic error terms on equations:

$$\frac{\theta_w}{T_w} + \frac{\varphi w}{wT_w - E_c' - \sum_{j \in G^R \cap A^f} P_j \alpha_j T_j} - \frac{\theta}{\tau - T_w - T_c - \sum_{k \in G^R \cap A^f} T_k} = u_1$$

$$\frac{\tilde{\theta}_k}{T_k} - \frac{\theta}{\tau - T_w - T_c - \sum_{k \in G^R \cap A^f} T_k} - \frac{\varphi P_k \alpha_k}{wT_w - E_c' - \sum_{j \in G^R \cap A^f} P_j \alpha_j T_j} = u_k$$

$$\tilde{\theta}_k = \theta_k + \varphi_k$$

Define *l=1* for work and *l=2,…,L* for activities in $G^R \cap A^f \quad (L = \left| G^R \cap A^f \right|)$

$$f_l\left(T_1, \ldots, T_{L+1}\right) = u_l \qquad l = 1, 2, \ldots, L+1$$

$$\mathbf{u} = (u_1, u_2, \ldots, u_{L+1})' \sim MVN_{L+1}(\mathbf{0}, \mathbf{\Omega})$$

A TIME ALLOCATION MODEL WITH EXTERNAL PROVIDERS (Jara-Díaz and Rosales-Salas, 2016)

$$MaxU = \Omega \mathrm{T}_{\mathrm{w}}^{\theta_w} \prod_i T_i^{\theta_i} \prod_d (T_d + T_{d_0})^{\theta_d} \prod_j X_j^{\varphi_j} \prod_d Z_d^{\varphi_d}$$

$$I + wT_w - \sum_d P_d(\sigma_d[T_d + T_{d_0}] + o_d H_d) - \sum_j P_j X_j - \sum_d s_d H_d - c_f \geq 0 \leftarrow \lambda$$

$$\tau - T_w - \sum_d T_d - \sum_d T_{d_0} - \sum_i T_i = 0 \leftarrow \mu$$

$$T_i - T_i^{min} \geq 0 \quad \leftarrow \kappa_i \quad \forall i$$

$$X_j - X_j^{min} \geq 0 \quad \leftarrow \eta_j \quad \forall j$$

$$(\epsilon_d[T_d + T_{d_0}] + \psi_d H_d) - Z_d = 0 \leftarrow \gamma_d \quad \forall d$$

Jara-Díaz et al. (2008) DeSerpa (1971)

Pollak and Wachter (1975) Becker (1965)

Reid (1934)

$$Value\ of\ leisure = \frac{\mu}{\lambda} = \frac{\Theta}{\Phi} \frac{(wT_w - E_c - \sum_d P_d(\sigma_d[T_d + T_{d_0}] + o_d H_d) - \sum_d s_d H_d)}{(\tau - T_w - \sum_d T_d - T_c)}$$

$$Value\ of\ work = \frac{\partial U / \partial T_w}{\lambda} = \frac{\mu}{\lambda} - w$$

Time Use Modeling: Results and control test (Dutch data)

Model estimation results for all individuals in all waves

Average values of time [euros/hr]								
	Total sample		Wave 1		Wave 2		Wave 3	
	Estimate	Std. Dev	Estimate	Std. Dev	Estimate	Std. Dev	Estimate	Std. Dev
Value of Leisure	28.926	42.494	38.607	39.388	16.386	26.316	32.162	64.738
Value of Work	13.802	46.331	25.387	38.027	0.329	23.365	16.054	66.488
Wage Rate	15.124	15.802	13.219	6.515	16.057	11.664	16.107	23.013
Ratio VoL - wage	1.913		2.920		1.020		1.997	
Ratio VoW - wage	0.913		1.920		0.020		0.997	
Number of observations	301		101		86		114	

Base model estimation results with no external agent, childcare as committed expenses and committed time (larger overestimation if considered free)

Average values of time [euros/hr]								
	Total sample		Wave 1		Wave 2		Wave 3	
	Estimate	t-stat	Estimate	t-stat	Estimate	t-stat	Estimate	t-stat
Value of Leisure	39.117	2.875	46.722	3.155	27.801	2.924	38.276	2.780
Value of Work	23.994	2.535	33.503	2.758	11.744	2.088	22.169	2.436
Wage Rate	15.124		13.219		16.057		16.107	
Ratio VoL - wage	2.59		3.53		1.73		2.38	
Ratio VoW - wage	1.59		2.53		0.73		1.38	
Sample size	301		101		86		114	

Conclusions

Travel time importance has been detected with choice models that represent a combination of the microeconomics of discrete choices and time use theories. The interpretation of travel time values depend on this underlying micro-framework.

Behind the WPSTT there are two components: relocation of time and perception of travel itself. Which one dominates is relevant. The estimation from discrete travel choice models includes both.

The value(s) of relocating time require the estimation of time use models. Data is an issue, but discussion on specification, segmentation, estimation and interpretation is equally important.

Combining time use data analysis and disciplinary contributions within time use modeling approaches has great potential but has not been explored exhaustively.

The value of household production and domestic work, and the effect of the trade-off between work and non-work activities such as leisure should allow a better estimation and improve the interpretation of the value(s) of time.

Time use analysis is a relevant part of the agenda on Transport Research

Beyond Transport Time: modeling time use, understanding time values.

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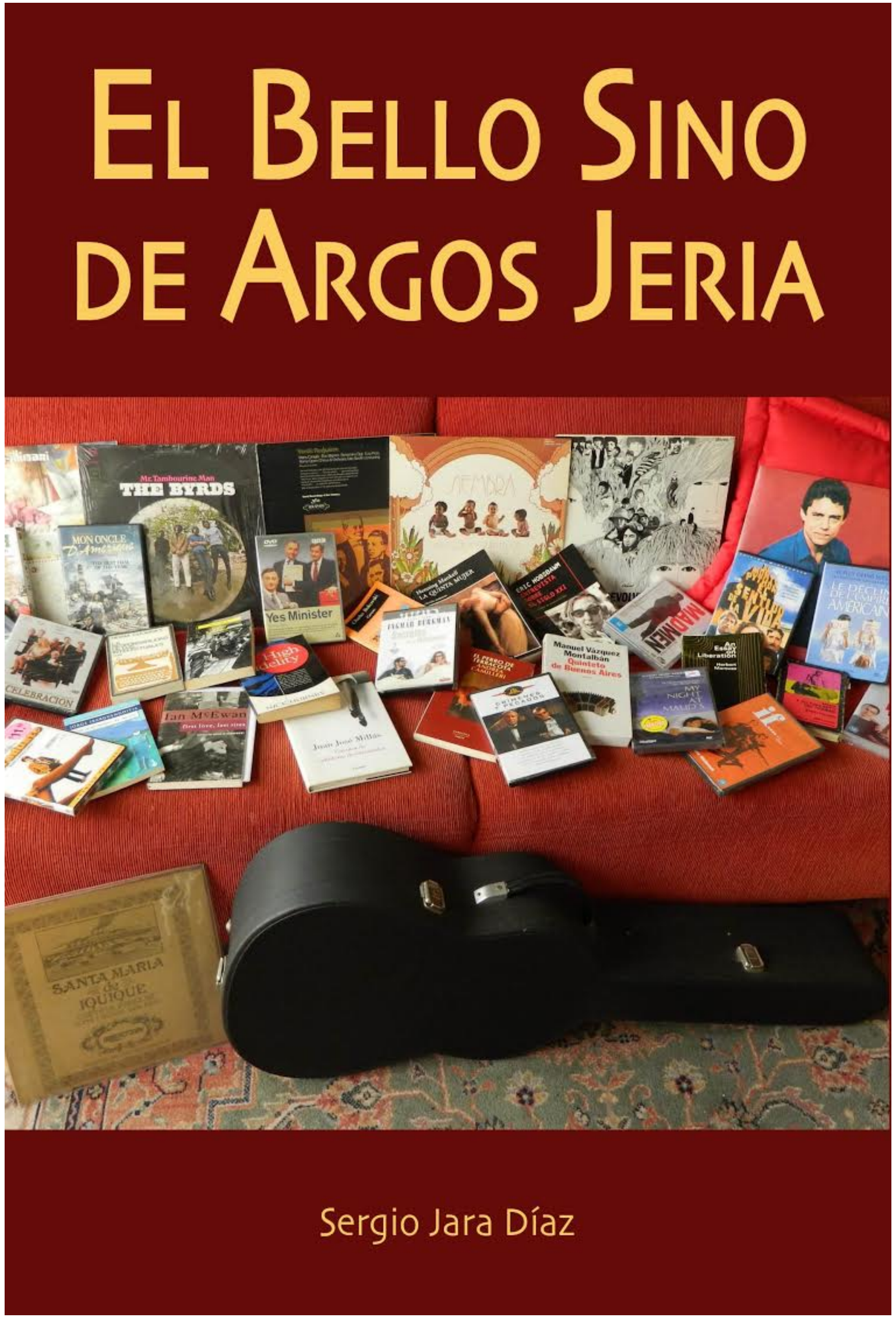
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de Argos Jeria
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